

MULTIMEDIA



UNIVERSITY

STUDENT ID NO

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MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2019/2020

EOP3026 OPTOELECTRONICS DEVICES

(OPE and NE)

21 OCTOBER 2019
9:00 A.M - 11:00 A.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 4 pages including cover page with FOUR questions.
2. Attempt **ALL** questions and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

- (a) Light emitting diode (LED) has become a popular choice of solid-state lighting owing to its energy saving capability in which the LED is made of a pn^+ -homojunction structure.
- (i) Sketch the energy band diagrams without bias and with forward bias conditions of the LED. Label the p -doped region, n -doped region and all energy levels on both diagrams. [3+3=6 marks]
- (ii) Describe the working principle of the LED. [7 marks]
- (b) The active layer of a GaAs LED is doped with acceptors with a concentration of $5 \times 10^{17} \text{ cm}^{-3}$. The emission wavelength is 830 nm, nonradiative mean lifetime is 80 ns and $B = 4 \times 10^{-16} \text{ m}^3 \text{ s}^{-1}$. The emitted optical power is 5 mW when a forward current of 20 mA is applied.
- (i) Calculate the emission photon energy. [3 marks]
- (ii) Calculate the radiative mean lifetime of a carrier. [3 marks]
- (iii) Calculate the internal quantum efficiency of the LED. [3 marks]
- (iv) Calculate the external quantum efficiency of the LED. [3 marks]

Question 2

- (a) Laser diode is used in long-haul, high-bandwidth optical communication system since it possesses higher optical output power and narrower linewidth as compared to that of a LED. However, laser diode requires a relative large threshold current to achieve the lasing condition. Discuss **THREE** methods that can be done to reduce the threshold current of a laser diode. [3×4=12 marks]
- (b) An infrared InGaAs-based laser diode has an active region which is defined by its width $W = 2 \text{ } \mu\text{m}$, thickness $d = 0.5 \text{ } \mu\text{m}$ and length $L = 100 \text{ } \mu\text{m}$. The mean spontaneous recombination time (radiative lifetime) is 6 ns and the threshold carrier concentration is $3 \times 10^{19} \text{ cm}^{-3}$, and the refractive index of InGaAs is 3.382.
- (i) Calculate the threshold current of the laser diode. [4 marks]

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- (ii) If the peak emission energy is 0.79 eV, calculate the peak emission wavelength and the other **TWO** closest allowed emission wavelengths around the peak emission wavelength that are amplified by the optical cavity of the laser diode. [6 marks]
- (iii) Based on the results obtained in **Q2(b)(ii)**, sketch the optical output spectrum of the laser diode. [3 marks]

Question 3

- (a) Figure Q3(a) shows a device structure of an InGaAs/InP separate absorption avalanche photodiode (SAM APD).

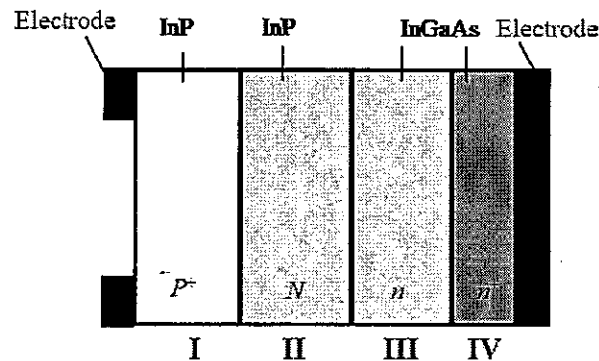


Fig. Q3(a)

- (i) Plot the electric field profile for region I, II, III and IV of the SAM APD. [3 marks]
- (ii) State the names for region II and III. [2 marks]
- (iii) What are the functions for region II and III? [4 marks]
- (iv) Discuss the design considerations for region II and III? [4 marks]
- (b) An InGaAs/InP SAM APD has a quantum efficiency of 65% at 1560 nm with unity gain. The APD is illuminated with an incident optical power of 5 nW.
- (i) Calculate the responsivity at unity gain, $M = 1$. [3 marks]
- (ii) Calculate the primary photocurrent. [3 marks]

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- (iii) Calculate the multiplied photocurrent when it is biased to operate with a multiplication of 20. [2 marks]
- (iv) Sketch the current-voltage characteristic curves for photocurrents at $M = 1$ and $M = 20$, and indicate also the reach-through and breakdown on the curves. [4 marks]

Question 4

- (a) Solar cell has been a promising candidate for renewable energy source which can be made from a pn -junction.
 - (i) Discuss **TWO** design considerations for the electrode of a solar cell. [4 marks]
 - (ii) Suggest **TWO** methods to improve light collection into a solar cell. [4 marks]
 - (iii) Discuss photocurrent generation mechanism of a n^+p silicon solar cell, where the n -region and p -region are respectively highly and lightly doped. [4 marks]
- (b) A 250 cm^2 silicon solar panel is exposed to a light intensity of 5 mWcm^{-2} and has an efficiency value of 22% and an open circuit voltage of 3 V. The power generated from the solar cell is then stored in a rechargeable battery with a load resistance value of 25Ω .
 - (i) Calculate the incident optical power received by the solar cell. [3 marks]
 - (ii) Calculate the current flows through the rechargeable battery. [4 marks]
 - (iii) Calculate the short circuit current if the form factor is 0.8. [3 marks]
 - (iv) Sketch the current-voltage characteristic curve of the solar cell. Label the short circuit current, open circuit voltage, current and voltage delivered to the rechargeable battery on the curve. [3 marks]

List of constants:-

Electronic charge, $e = 1.602 \times 10^{-19} \text{ C}$

Planck's constant, $h = 6.626 \times 10^{-34} \text{ Js}$

Speed of light, $c = 3 \times 10^8 \text{ ms}^{-1}$

Temperature [Kelvin], $T = T [^\circ\text{C}] + 273$

Boltzmann constant, $k_B = 1.381 \times 10^{-23} \text{ JK}^{-1}$

End of Paper